Food and Agriculture Organization of the United Nations

Climate change mitigation and adaptation in agriculture, forestry and fisheries

International treaties and national policies seek to enhance global efforts to mitigate and adapt to climate change. While it is important to continue to strive to reduce greenhouse gas emissions, mitigation alone is not enough and will not be felt before the second half of the century. Global warming is already underway and adaptation strategies are now a matter of urgency, especially for the most vulnerable poor countries, which are even now being disproportionately affected.

Changing climate, changing agriculture

Historically, farmers, pastoralists, forest dwellers and fishers have learned to cope with climate variability and have often adapted crops and farming practices to suit new conditions. But the severity and pace of climate change is presenting new, unprecedented challenges. The poor in rural and urban areas will be most adversely affected as they depend on climate sensitive activities and have a low capacity to adapt. Gradual changes in temperatures and precipitation as well as more frequent extreme weather are expected to result in crop failures, livestock deaths and other asset losses, thereby threatening food production but also access, stability and utilization of food resources. In some areas, the changes may well exceed the adaptation capacity of populations.

Agriculture is not only the victim of climate change, it is also a source of greenhouse gases. Crop production and livestock release greenhouse gases into the air and are responsible for the major part of the emissions of methane (from cattle and wetlands, especially rice paddies) and nitrous oxide (from fertilizer use). Changes in land use such as deforestation and soil degradation – two devastating effects of unsustainable farming practices – emit large amounts of carbon into the atmosphere, contributing to global warming.

Farmers and pastoralists can play an important role in reducing global emissions by planting trees, reducing tillage, increasing soil cover, improving grassland management, altering forage and animal breeds and using fertilizer more efficiently among other measures. By maintaining higher levels of carbon in the soil – a process known as "soil carbon sequestration" – farmers can help reduce carbon dioxide levels in the air, enhance the soil's resilience and boost crop yields.

Successful approaches to adaptation

Adaptation strategies are beginning to take shape as governments, businesses and communities worldwide grow to understand climate change and how urgent it is to address current and potential impacts. To be successful, adaptation measures need to appeal to local practices and vulnerabilities. Planning at the household, community and national levels can limit the damage caused by climate change, as well as the long-term costs of responding to climate-related impacts that are expected to grow in number and intensity.

The adaptation challenge will be greatest for developing countries. At lower altitudes, these countries are more exposed to the most severe impacts of climate change, including flooding, drought and increased incidence of pest and diseases. Together with a high reliance on climate-sensitive activities, such as agriculture and fishing, lower per capita incomes, weaker institutions and limited access to technology and markets this makes many developing countries highly vulnerable to climate change. These countries will need international support to adapt to our new changing environment.

The most effective adaptation approaches in developing countries will be those that address a range of stresses and factors, including land tenure, armed conflict, food insecurity, massive migration and diseases such as HIV/AIDS. Evolving resilient, holistic and secure food systems that can adapt to climate change and other stress factors is the key. Sustainable development and the Millennium Development Goals must serve as a basis for any adaptation policy.

Key facts

- Agriculture and deforestation account for about one third of global greenhouse gas emissions from human activities, specifically 25 percent of carbon, 50 percent of methane and over 75 percent of nitrous oxide.
- About 80 percent of total emissions from agriculture, including deforestation, are from developing countries.
- Climate change is expected to increase the number of undernourished people and may reduce yields of rainfed crops in some African countries significantly as early as the 2020s.
- According to some projections, half of all agricultural land in Latin America is likely to be affected by desertification and/or salinization by 2050.
- Adaptation in developing countries is estimated to cost tens of billions of US dollars annually over the next decades.

An effective adaptation approach is to promote diverse, flexible livelihoods across sectors that reduce people's dependence on climate-sensitive resources. For example, aquaculture and agriculture systems can be integrated to allow rural communities to shift their activities as the suitability of the land and water shifts. Diversifying rural enterprises may reduce farmers' income in the short term but it will ultimately protect them against possible food shortages and other vulnerabilities in the future.

Putting policies in place

The next 10 to 15 years is the generally agreed upon window in which the international community must mobilize global financing and put long-term adaptation plans in place. While the majority of least developed countries has already prepared National Adaptation Programmes of Action, their implementation will be a challenge. Many adaptation measures will focus on strengthening measures that already exist, such as early warning systems, systems to identify climate change "hot spots" and disaster risk management. Others will focus on rural investments to reduce the long-term effects of short-term climate variability on food security, through crop insurance (*see* Insuring against weather-related crop failure *below*) and incentives that encourage farmers to adopt better agricultural and land use practices.

Policies need to be integrated across levels and sectors and should take advantage of potential synergies between climate change mitigation and adaptation as well as food security and sustainable development. Similarly, agricultural constituencies should regularly participate in international climate change negotiations.

Building capacity and awareness in developing countries will also be essential. National extension and agronomic research services have an increased role to play in data collection, analysis and dissemination. Governments and local communities need to be up-to-date on the latest climate-related research, methods and tools, including local impact assessments and funding mechanisms such as the carbon market funds. With regard to adaptation, decision makers at all levels must maintain the capacity to make continuing adjustments following a "learning by doing approach".

Insuring against weather-related crop failure

Weather-based index insurance is a relatively new risk management tool that links insurance payouts to objective, measurable variables like rainfall or temperature. Such insurance policies allow farmers to better manage risk and encourage them to invest in agricultural activities that require a higher initial investment. Because triggers can be verified independently, there is far less likelihood of fraud or political interference, making banks and insurance companies more likely to provide index insurance to poor rural communities. Payouts are proportional to the difference in rainfall or temperature, and thus only provide farmers with partial protection. Smallholder farmers in a 2005 study in Malawi reported that index insurance was their primary strategy for climate change adaptation.

Glossary

- **Adaptation**: actions by individuals or systems to avoid, withstand or take advantage of current and projected climate variability, changes and impacts. Adaptation decreases a system's vulnerability or increases its resilience to impacts.
- **Adaptive capacity**: a system's inherent ability to adapt to climate change impacts.
- **Mitigation**: actions to reduce greenhouse gas emissions by sources and/or enhance carbon removal by sinks.
- **Resilience**: the ability of a system to withstand negative impacts without losing its basic functions.
- **Vulnerability**: the potential for a system to be harmed by climate change, considering the impacts of climate change on the system as well as its capacity to adapt.

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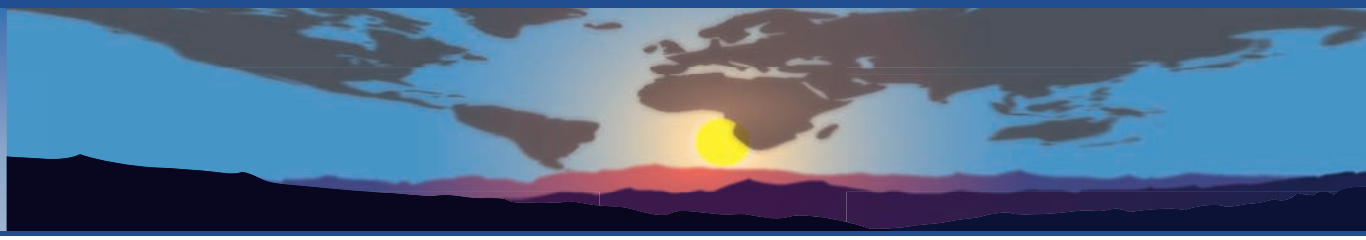


Climate change and biodiversity for food and agriculture

As climate changes, the value of biodiversity for food and agriculture will increase. Genetic resources are the living material that local communities, researchers and breeders use to adapt food and agricultural production to changing needs. Maintaining and using this reservoir of genetic diversity will be the foundation for coping with climate change.

Genetic erosion

At the same time, climate change will be an important driver of genetic erosion in the future. It will both threaten the survival of individual species and affect the way different elements of biodiversity interact in food and agriculture ecosystems. These interactions provide "services", such as pollination, soil fertilization and the natural biological control of plant and animal pests and diseases, that are essential for food production. Smallholder and subsistence farmers and pastoralists will be the hardest hit by disruptions in these services.

This irreversible loss of biodiversity will have serious consequences for global food security. If coordinated efforts are taken at the national and international levels, biodiversity can be conserved and harnessed to help food and agriculture adapt to climate change.

What is at stake?

The Intergovernmental Panel on Climate Change reports that a significant number of species will be at risk of extinction as the global mean temperature increases. Of particular concern are relatives of major crops surviving in the wild. Crop wild relatives are already under severe threat due to habitat loss and environmental degradation. Climate change, which may make their remaining habitats unsuitable for their survival, may drive them to extinction. Research by the Consultative Group on International Agricultural Research based on distribution models (*see maps overleaf*) of wild relatives of three staple crops of the poor – peanuts, cowpea and potato – suggests that by 2055 16 to 22 percent of wild species will be threatened by extinction.

In some areas, food is still gathered from the wild. Genetic erosion represents an immediate threat to the well-being of rural communities. Loss of genetic diversity can also have serious long-term consequences globally. Plant wild relatives may contain the genes for traits that could be used to breed new crop and forest varieties that can meet the challenges of climate change.

Livestock breeds and fish with limited geographic distribution may also face the risk of extinction because of climate change and the increased frequency of natural disaster (droughts, flooding, major storms) associated with it. For example, tilapia, a fish species vital to the food security of millions, originated in areas of Africa where the impact of climate change is expected to be extreme. Loss of genetic diversity in tilapia subspecies, many of which can only be found in African lakes and rivers, would decrease the breeding options for this species worldwide.

Climate change adaptation and mitigation

Researchers and local communities need to reach into the planet's vast genetic reservoir to breed new plants and animals that will thrive in a warmer world and meet the food requirements of an expanding population. For many small-scale and subsistence farmers, adapting to changing conditions may be difficult. The rate of climate change suggests that in many instances locally available genetic diversity will be unable to adapt quickly enough to survive. In these cases, collecting and conserving the threatened diversity will be crucial. Crop varieties or species better suited to new growing conditions may need to be introduced. In the livestock sector, this sort of substitution has already begun. In some drought-prone areas of Africa, pastoralists are switching to raising camels instead of sheep and goats.

Key facts

- The 2005 Millennium Ecosystem Assessment estimates that by the end of this century, climate change will be the main cause of biodiversity loss.
- The Intergovernmental Panel on Climate Change asserts that roughly 20 to 30 percent of species it has assessed are likely to be at increasingly high risk of extinction as global mean temperature exceeds pre-industrial levels by 2 to 3° C.
- Many livestock breeds cannot be genetically improved fast enough to adapt to climate change.
- Coping mechanisms based on local biodiversity are particularly important for the most vulnerable people, who have little access to formal employment, land or market opportunities.

The increased use of biodiversity for food and agriculture, particularly soil microorganisms, also has the potential to mitigate climate change by reducing the accumulation of greenhouse gases in the atmosphere. Harnessing local biodiversity can maintain the health of forests and the fertility of agricultural soils, both of which are important carbon sinks. It can also reduce the need for nitrogen-based fertilizers, a major source of greenhouse gases, and other energy-intensive commercial inputs.

What is to be done?

There is an urgent need to determine the distribution of biodiversity for food and agriculture both in the wild and in the fields and assess its vulnerability to climate change. Matching biodiversity distribution mapping with different climate change scenarios is a basic requirement for countries to develop conservation strategies. Information is also needed about the biodiversity held in national and international gene banks. The potential to harness this biodiversity to cope with climate change remains untapped, largely due to a lack of information on the characteristics of the genetic diversity conserved and their performance in the field. Global information systems that can store and manage this data and make it accessible to researchers, breeders and farmers are essential.

This information and analysis needs to be integrated into future reports of the Intergovernmental Panel on Climate Change. And the panel's climate change data and projections need to be incorporated into FAO's global biodiversity assessments.

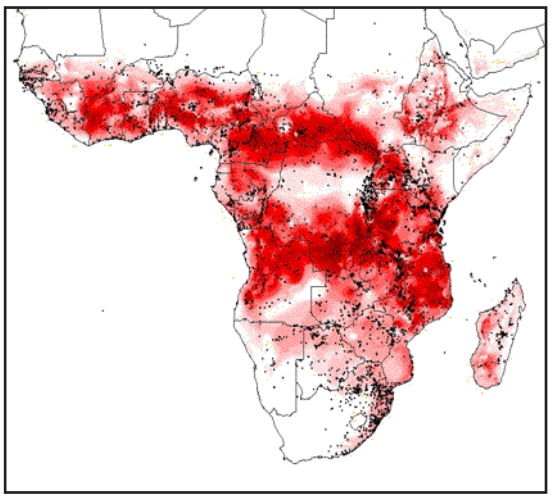
Farmers at the forefront

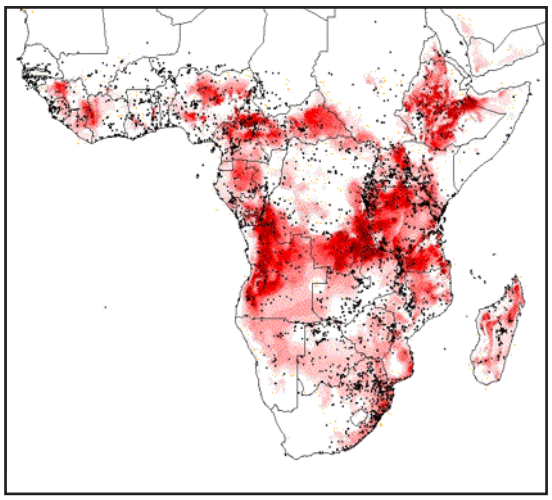
Rural communities have the largest stake in developing strategies to cope with climate change, and understanding how they are currently using biodiversity to cope with climate change should be the basis for future actions. Men and women farmers, pastoralists and fisherfolk and their local institutions need to be given access to information about climate change and the ways locally available biodiversity can help them adapt.

Access to agricultural biodiversity will determine whether a given strategy is feasible. Governments must ensure that rural communities have access to the biodiversity they need. Especially important will be global exchange mechanisms that can ensure every country has access to genetic resources for food and agriculture and that can guarantee the fair and equitable sharing of the benefits arising out of their use.

Decline of a strategic resource

Projections suggest that by 2055 climate change will cause the dramatic decline (map on right) of the important genetic resource wild vigna (related to the African staple cowpea, an important and inexpensive source of protein) from its current distribution and genetic diversity (map on left).





Source: Jarvis, A., et al., The effects of climate change on crop wild relatives, Agric Ecosyst Environ (2008)

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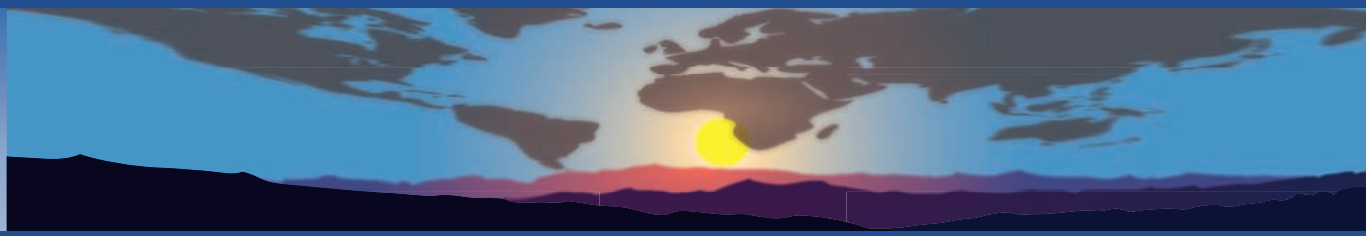

Bioenergy and food security

Bioenergy presents both opportunities and risks for food security. It could revitalise the agriculture sector, foster rural development and alleviate poverty, not least by improving rural access to sustainable energy. But if not managed sustainably, it could seriously threaten food security, hindering access to food for some of the most vulnerable.

The current situation

Bioenergy can help mitigate climate change, but not if forests and peatlands are cleared to cultivate energy feedstocks. Producing biofuels from agriculture and forest residues may offer an alternative, but the technology is not yet commercially viable. Policy makers face the challenge of calculating how to exploit bioenergy opportunities while ensuring that people can continue to grow or buy adequate supplies of food.

For millennia, households have used bioenergy in the form of biomass from wood and organic wastes. This "traditional" bioenergy provides up to 95 percent of energy needs in developing countries (*see* Biomass: energy source for 2.4 billion people *overleaf*). Interest in developing modern bioenergy forms, such as liquid biofuels, emerged in the 1970s. Today, desire for more diverse energy supplies, concerns about climate change, and record-high crude-oil prices are driving its growth. Bioenergy can contribute to climate change mitigation, but the potential varies greatly between different feedstocks, locations and methods.

Bioenergy production can benefit rural development and reduce poverty by increasing employment and creating new market opportunities. Modern bioenergy sources are also a promising source of cleaner and more efficient energy for rural areas. However, harnessing these benefits requires mechanisms that promote participation by small-scale farmers and poor people.

Recently, liquid biofuels for transport have experienced the most growth. Developing countries in tropical zones have a comparative advantage in growing feedstocks for biofuels, but current demand growth is strongest in industrialized countries. Feedstock for current biofuels comes from food crops, including sugarcane, maize, oil palm and canola, affecting food supply. Biofuel production also competes for natural resources such as land and water and causes land use change. Competition can be reduced with improved technologies, such as by converting cellulose into energy, and production of new energy crops on land unsuitable for growing food.

The production and consumption of liquid biofuels is highly concentrated. Approximately 90 percent of ethanol is produced in the United States and Brazil, while biodiesel is mostly produced in Germany and France. Today's biofuel market, particularly in OECD countries, is driven by measures – mandates, subsidies, tax incentives, and tariffs – that favour domestic production and hinder international trade.

How food security will be affected

Risks to food security through higher prices are greatest where bioenergy is based on food crops or uses land and water that would otherwise go for food production. This competition is more acute in producing liquid biofuels than in biomass for heat and power. Based on current technology, the rapid expansion of liquid biofuels is contributing significantly to rising food prices. This benefits rural farmers with surplus to sell but hurts urban consumers and the rural poor who must buy food. Pressures on food supply can be reduced through technologies that make use of degraded or marginal lands, sustainably intensifying production, integrating food and energy production systems and appropriate farming practices.

Food security may improve locally where the demand for feedstocks drives investment in agriculture, creates new employment and market opportunities for small

Key facts

- Bioenergy meets approximately 10 percent of global energy demand, around 80 percent of it as solid biomass for heating and cooking.
- Liquid biofuels account for less than 2 percent of road transport fuels worldwide; this is projected to rise to nearly 5 percent by 2030.
- Brazil's biofuel sector accounted for about 1 million jobs in 2001, mostly for unskilled workers in rural areas.
- In 2007/08, in the United States around 27 percent of the maize crop is projected to be used for ethanol.

producers, and revitalizes the rural economy. To what extent households can benefit from this will vary according to population and income, location, age and gender, and with the production system – large plantations or individual farms. Large-scale plantations could provide jobs for labourers but might displace small-scale farmers. Support for outgrower schemes and cooperatives and pro-poor bioenergy policies that ensure land tenure security for marginalized farmers could help mitigate the negative effects.

What is to be done?

Policy-makers have a major role in ensuring that bioenergy is developed sustainably, safeguarding food security and ensuring that benefits reach the poor and vulnerable. Policy priorities include market and technology promotion, participatory processes and social protection:

- Safety nets: to mitigate impacts of higher food prices, the poor and food-insecure will need support such as food vouchers or other targeted subsidies.
- Policies: especially in promoting liquid biofuel, policies should be market-oriented, eliminating distortions that create artificially high growth rates and hamper international trade for developing countries. Bioenergy policies should also promote environmental sustainability and foster market opportunities for smallholders and other vulnerable groups.
- Price transmission: if farmers receive higher commodity prices, they will be more motivated to expand production and raise productivity. This requires investing in market institutions and physical infrastructure and preventing export restrictions.
- Better farming practices: practices that increase productivity, mitigate environmental impacts and/or integrate better food and energy production are needed. This requires financial support, more inputs and access to appropriate technologies.
- Technologies: improved technologies should be developed and promoted to reduce competition for food and natural resources.
- Stakeholder participation: including small-scale farmers and rural communities in decision making on bioenergy development will enhance rural development benefits.
- Extension services: upgraded extension services and stronger institutions will be needed.

Biomass: energy source for 2.4 billion people

The majority of poor rural people already rely on traditional bioenergy for their energy needs. Traditional used for heating and cooking, it is not very efficient and has been linked to indoor air pollution, accelerated deforestation, land degradation and soil erosion. The challenge is to develop energy systems that generate jobs without displacing people or hampering food security and improve local access and use of cleaner and more efficient energy sources. For example:

- Producing bioenergy from crop residues unsuitable for use as fertilizers could provide energy for rural areas
- Feedstock could be produced on individual farms, but this will require appropriate systems to collect, transport, store, handle and process the fuel. Large-scale systems can include poor farmers by adopting plantation-outgrower schemes under fair price contracts.

Efficient industry-based systems can supply energy for both industries and communities. Cogeneration plants using waste from sugarcane production provide close to 40 percent of the energy in Mauritius.

Brazil: linking small farms and big biofuel producers

Brazil's poor farmers benefit from biofuel production through the Social Fuel Seal (*Selo Combustível Social*) programme. Biodiesel producers who buy feedstocks from small family farms in poor regions pay less federal income tax and can access finance from the Brazilian Development Bank. By the end of 2007, 400 000 small farmers had joined the scheme. The farmers are organized into cooperatives and receive training from extension workers. During the national petroleum agency's biodiesel auction in December 2007, 99 percent of the fuel sold came from companies with the Social Fuel Seal.

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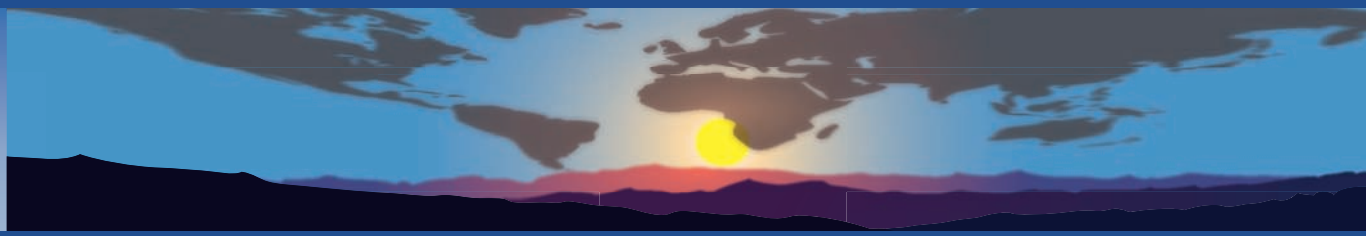


Climate change and disaster risk management

Natural disasters are on the increase, with the prospect of more frequent and more severe occurrences fuelled by global warming. In emergencies, it is the most vulnerable – the poor, elderly, women and children – who suffer the most from hunger and deprivation. Disaster risk management will play an increasingly key role in dealing with the effects of climate change on food security.

An uncertain future

Intense tropical cyclones, heat waves, severe downpours, droughts, floods, extreme winds and rising sea levels – global warming will likely lead to more natural disasters, which will affect food production. However, the impact will not be even. People living in high and mid-latitudes such as northern Canada, Siberia and Scandinavia will find it easier to grow crops, while those in areas already suffering food scarcity may face additional production risks.

Climate change impact models predict that some regions that at present grow cereals will lose areas of farmland. These include eastern, southern and western Europe, Central America and the Caribbean, Oceania and Polynesia, East, North, West and southern Africa, and South Asia.

North and southern Africa will be particularly hard hit, and sub-Saharan Africa according to some models may suffer cereal production losses of up to 33 percent by 2060. Latin America will see a loss of crop and livestock productivity and a drop in water supplies. In Asia, populous river deltas will experience floods, droughts and diminishing fresh water, which will affect food security.

Who is vulnerable?

Because of their greater reliance on agriculture, the poorest developing countries are most at risk from impacts of climate change. Already these countries – generally African – experience erratic rainfall and suffer consequent food shortages. Increased numbers of tropical cyclones will damage crops, causing local food shortages.

Much has been said about climate change and changes in food production. However, food security must also take into account stability of food supplies (affected by extreme weather events), the use of food (with warmer temperatures food will be less safe with increases in food poisoning and diarrhoea), and access to food (the food may be available but price rises caused by natural disasters may put food out of reach of some people).

Managing risk

People have coped with disaster for thousands of years. Experiences need to be gathered, analysed and systematically used to improve local level disaster response planning and programming. New solutions also will be needed. We have to assess how useful past experiences can be in the context of the never before seen scale and speed of change likely to be caused by climate change.

At the community level, people can be trained in better risk prevention and preparedness. To that end rural organizations, such as Farmer Field Schools, should be strengthened. Technologies and systems to monitor local conditions should be developed to help local farmers and authorities know in as much detail as possible how climate change will affect their areas. In order to minimize the impact of climate change on hunger, a multi-pronged approach is needed, at national, regional and international levels.

Key facts

- A breakdown of agricultural systems as a result of increased exposure to drought, rising temperatures and more erratic rainfall could leave up to 600 million more people facing malnutrition.
- Between 2000 and 2004 around 262 million people were affected by climate disasters. Of these 98 percent lived in developing countries.
- Twenty percent of the world's population live in river basins likely to be flooded.
- Since the 1970s, drought has increased in the Sahel, the Mediterranean, southern Africa and parts of South Asia.
- By 2020 between 75 and 250 million people in sub-Saharan Africa are expected to have less water. In areas where agriculture is dependent on rainfall, yields could drop by 50 percent.
- In the United States, damage from a storm like Hurricane Katrina can reduce Gross Domestic Product by 0.5 percent, but in Viet Nam one strong typhoon reduces GDP by 1-3 percent.

Climate change and disaster risk mamagement

There needs to be closer cooperation between climate change scientists, who make projections well into the future, and groups working on disaster risk management and food security, who deal with the here and now.

New ways of funding efforts to address climate risks and food security should be explored. These include microfinance tools for communities and households; expanding the role of the private sector; increasing the role of foundations; and enabling the rural poor to access the carbon credit market system.

In the short to medium term

Much can be done now and in the next few decades to lessen the worst effects of global warming. These measures include:

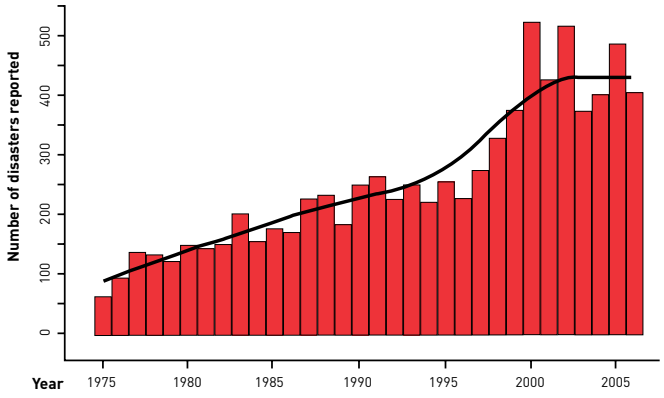
- developing climate models that give a better understanding of how climate may affect farming and forestry at a local level in order to be better prepared;
- diversifying livelihoods and adapting agricultural, fishing and forestry practices by encouraging better water management, soil conservation, resilient crops and trees;
- improving and expanding weather and climate forecasting;
- improving early warning systems

In the long term

To better adapt to climate change impacts:

- Land use plans must be adjusted.
- Cost/benefit analyses are needed to take account of climate change risks for irrigation or coastal protection.
- Contingency plans are necessary, taking into consideration new and evolving risk scenarios.

Natural disasters reported 1975-2006



Source: OFDA/CRED International Disaster Database

Proof that risk management saves lives

The value of disaster preparation was dramatically highlighted following Cyclone Sidr, which hit Bangladesh in 2007 with winds of up to 240 km/h. Nearly 6.8 million people were affected, 1.2 million houses destroyed and 2 997 people killed. Disastrous as this was, the death toll was greatly reduced from previous cyclones, which in 1970 killed 300 000 to 400 000 Bangladeshis, and in a 1991 cyclone, a further 130 000 to 140 000. Much of the credit for reducing the loss of life can go to the Bangladesh Government, assisted by USAID, which took disaster risk reduction measures and increased preparedness. These measures included building flood and cyclone shelters, wave protection walls and earth embankments. Early warning was given 10 days before the storm hit, 3 000 000 people were evacuated to safety and humanitarian relief personnel were predeployed to the area to be ready to help in the aftermath.

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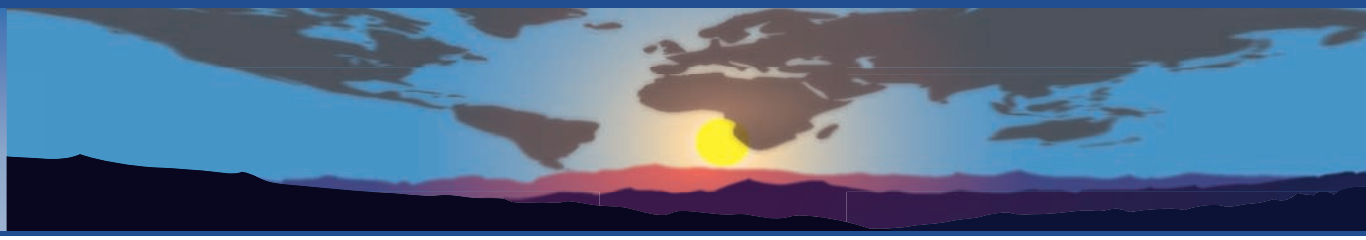

Climate change, fisheries and aquaculture

Fisheries and aquaculture are threatened by climate change: higher water temperatures, rising sea levels, melting glaciers, changes in ocean salinity and acidity, more cyclones in some areas, less rain in others, shifting patterns and abundance of fish stocks. Climate change compromises the sustainability and productivity of a key economic and environmental resource, but it also presents opportunities, especially in aquaculture. Developing countries that depend on fish for food and exports will have a real challenge adjusting to the changes.

Impacts of climate change

Oceans, especially at mid-latitudes and the tropics, are warming and parts are becoming more saline. But in the subarctic Atlantic, the Southern Ocean and parts of the Pacific, oceans are becoming fresher. Increasing acidification threatens coral reefs, which are also endangered by rising temperatures that cause bleaching. Climate change affects the intensity and frequency of sea currents, which flush and clean continental shelf areas in 75 percent of the world's major fishing grounds.

Eighty percent of the world's freshwater fisheries are in Africa and Asia. Parts of both continents will experience greater warming than the global annual average, resulting in less rainfall and lower lake levels. Already lake levels are dropping, mainly because people are using more water.

The oceans in the tropics and mid-latitudes will be less productive but, by contrast, cold water oceans will see greater productivity. Many fish cannot tolerate swift rises in temperature. Fish distribution patterns will change, with the strongest and most rapid change to fish stocks at the edges of their species' range.

Species, particularly those with shorter life spans, will change the timing of their life cycle. Some plankton species will bloom earlier, resulting in mismatches between the early life stages of fish and their prey, and therefore declines in abundance.

Coral reefs are habitat for many of the world's marine species. Climate change threatens them in two ways: it causes coral reef bleaching and destruction while increased ocean acidity interrupts calcification. Corals cannot easily move into higher latitudes because there are no suitable surfaces where they can develop.

Risks to diet and food security

Fisheries and aquaculture play a crucial role for food supply, food security and income generation. Some 42 million people work directly as fishers and fish farmers, with hundreds of millions more engaged in associated activities – the great majority in developing countries. Fish exports boost foreign currency earnings – particularly important in developing economies. In fact, aquatic foods are the most widely traded foodstuffs, outpacing agricultural products.

Fish is a major source of protein in many poor people's diets, which are often dominated by starchy staples. Fish comprises about 20 percent of animal protein in the diets of over 2.8 billion people – and can reach 50 percent in the world's poorest regions, notably Africa and South Asia, and up to 90 percent in small island developing states and coastal areas.

Impacts of climate change will affect fisheries- and aquaculture-dependent people as production and marketing costs increase, buying power and exports decrease and dangers from harsher weather conditions rise. Small fishing communities in some areas will face greater uncertainty as availability, access, stability and use of aquatic food and supplies diminish and as work opportunities dwindle.

Developing countries are at greatest risk. In sub-Saharan Africa, Angola, Congo, Mali, Mauritania, Niger, Senegal and Sierra Leone are the most vulnerable countries. Semi-arid and with significant coastal or inland fisheries, they export large quantities of fish. Earnings from fish exports can be equivalent to 50 percent of the cost of their food imports.

Key facts

- Fisheries employ more than 200 million people worldwide – 98 percent from developing countries.
- Small-scale fisheries support 99 percent of fishers but produce less than 50 percent of all fish.
- Aquatic products provide at least 50 percent of animal protein and minerals to 400 million people from the poorest African and South Asian countries.
- Countries most vulnerable to fisheries- and aquaculture-related climate change include those in West and Central Africa, northwest South America, and Southeast Asia.

Climate change, fisheries and aquaculture

Most of the people who work in small-scale fisheries are from developing countries. If fish distribution changes due to global warming, fishers with their small boats will be unable easily to follow the fish to new fishing grounds. These coastal populations also are threatened by more frequent storms and sea level rise.

River-dependent Asian fisheries, such as in Bangladesh, Cambodia and Pakistan, are also vulnerable to climate change as the abundance and diversity of riverine species are particularly sensitive to climatic disturbances.

Aquaculture: new opportunities

Now accounting for 45 percent of global seafood consumption, aquaculture production will continue rising to meet future demand. Here, climate change offers new opportunities. Production in warmer regions will likely increase because of better growth rates, a long growing season and the availability of new fish farming areas where it was once too cold. Aquaculture development opportunities will increase in some areas. This is particularly significant in tropical and sub-tropical regions, such as in Africa and Latin America.

At the same time, extreme weather events such as floods and cyclones could damage fish farms. In cool and temperate regions mollusc and salmon farms will be adversely affected by warming as the fish will not be able to survive algal blooms and new pathogens caused by higher temperatures.

Adaptation and mitigation strategies

Adaptation strategies should be based on an "ecosystem approach", defined as a comprehensive and holistic approach to understanding and anticipating ecological change, assessing the full range of consequences, and developing appropriate management responses. In support of such an approach, ongoing study of the climate change phenomenon and its impact on the fisheries ecosystem will be crucial.

Although a relatively small contributor of greenhouse gas emissions, there are certainly areas in which fisheries and aquaculture have a responsibility to limit such emissions as much as possible. Decreasing carbon dioxide emissions will also improve the aquatic ecosystems' ability to respond to external shocks. For example, eliminating inefficient global fleets and fishing practices would reduce fuel needs; increasing efficiency of aquatic farms would decrease water and energy use; and reducing post harvest losses as well as increasing waste recycling will shrink the sector's carbon footprint.

Providing the best possible conditions to assure food security – quantity, access, use and timing of supply – calls for responsible management and governance. The FAO Code of Conduct for Responsible Fisheries and relevant international plans of action can be used as a basis for action.

Nigeria: variable access rights in a variable climate

As global warming dries out fresh water fisheries, communities may have to adapt simply by sharing the dwindling resource. Lessons in how to do it equitably could be learned from the fishers of the Nguru-Gashua wetlands in northern Nigeria. During the flood season, fishers have open access to the wetlands. But when the floods recede the deep sections of the river are managed by village water management councils. Fishers either pay for the right to use the deep sections or give up part of their catch to the council; outsiders must seek permission. Parts of the river are fished one at a time. Individuals or families own floodplain pools; they must give up part of their catch to the village, the proceeds of which are used in community development projects.

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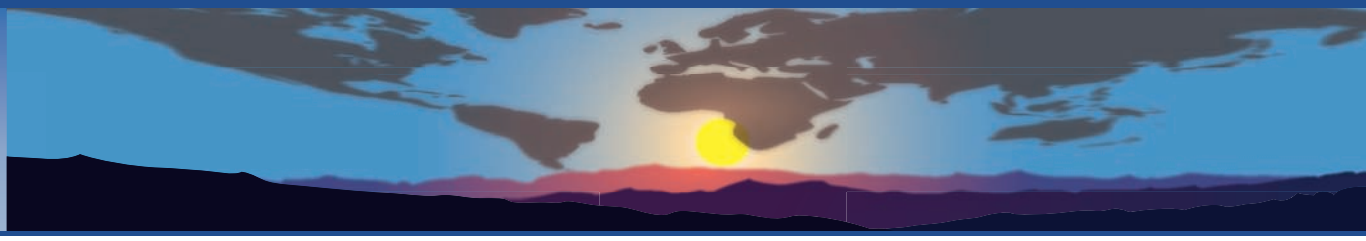

Climate change, biofuels and land

Climate change and expanding biofuel production is likely to lead to greater competition for access to land. For the millions of farmers, pastoralists, fisherfolk and forest dwellers with no formal land tenure rights, this increased competition poses a tremendous threat to their livelihoods. Sound land tenure policies and planning will be crucial to ensuring that these men and women do not fall into even greater hardship.

Unfamiliar territory

Climate change threatens to uproot many rural communities. For example, rising sea levels may force many communities living in low-lying coastal areas and river deltas in developing countries to move to higher ground. Similarly, increasingly frequent droughts brought on by climate change may leave farmers and pastoralists who rely on rainfall to raise their crops and livestock with no alternative but to abandon their lands.

This displacement of people is likely to result in competition between migrants and established communities for access to land. Reconciling diverse land use needs presents daunting challenges for governments at all levels. In cases where land rights are informal and different customary land tenure systems coexist, governments will need to work closely with local communities to establish fair and equitable systems of land tenure and develop mechanisms for resolving disputes. For many displaced communities, it may be impossible to maintain their farming or pastoral traditions. Land tenure policies designed to facilitate resettlement will need to be incorporated into a broader programme that provides opportunities for the displaced to earn livelihoods outside the agricultural sector.

Changing values

The expansion in cultivation of biofuel crops, driven not only by efforts to mitigate climate change but by high oil prices and national efforts to achieve energy self-sufficiency, will also trigger greater competition for land. Countries seeking to capitalize on heightened demand for biofuels may choose to expand biofuel production by expropriating land being used by small-scale and subsistence farmers and allocating it to outside investors. From the perspective of national economic planners, the land may be considered "idle" or may not satisfy requirements for "productive use". For local farmers and pastoralists, however, access to this land may be their most valuable asset. When the land is expropriated, it can be difficult for local users, especially if they hold no formally recognized tenure rights, to negotiate sufficient compensation to ensure a sustainable livelihood.

In some areas, the move to expand biofuel production may provoke a shift in customary land tenure systems. Individual rights to the land acquired through a commercial real estate market may replace communal lands rights. In these cases, those who can afford market prices will secure greater control over the land, but many more risk losing their access to the land. In situations where real estate markets already determine land values, expanded biofuel production may drive up land prices. Low-income farmers may find themselves priced out of the rental market and see their access to land and their livelihoods disappear.

Rights denied

As land availability and land values change, some groups are at a greater disadvantage than others. Indigenous communities for example are particularly vulnerable because many governments do not recognize the legitimacy of their land and territorial rights. In addition, many indigenous peoples occupy territories that are particularly vulnerable to climate change, such as mountain and polar lands where melting glaciers and ice sheets may disrupt the supply of fresh water available and significantly alter the distribution range of fish and

Key facts

- In Africa more than 90 percent of land remains outside the formal legal system.
- Women produce about half of the world's food but they own only about two percent of all land.
- It is estimated that low-lying river deltas, which are at risk from flooding due to rising sea levels brought about by climate change, are home to nearly 300 million people.
- Projected growth in biofuel production to 2030 will require 35 million hectares of land (*see table*), an area approximately equal to the combined area of France and Spain.

wildlife populations. In the world's remaining tropical rainforests, long-term drying trends will have a tremendous bearing on plant and animal species and the natural resources on which indigenous forest communities depend.

As competition for land increases under pressure of climate change and the expansion of biofuel cultivation, women are also disproportionately disadvantaged. In many parts of the world, because of entrenched legal and institutional discrimination, women do not hold formally recognised land rights. They often may face discrimination in customary tenure systems as well. Although women play a major role in agricultural production, childcare and gathering domestic water and fuel supplies they often have little control over how the land and other natural resources are managed. When populations are forced to resettle to new lands or communally held land is appropriated, it is rare that women's needs and priorities are considered.

Security and flexibility

Given that climate change and the expansion of biofuel production is likely to affect access to land by the poor, there is a need for land policies that provide greater land tenure security to disadvantaged groups. Greater land tenure security also serves to mitigate climate change. Farming and forest communities are more likely to invest in agricultural practices that sustain healthy forests and fertile fields, both of which are important carbon sinks, if they have secure land tenure.

As competition for land increases, there is a need to ensure that the land rights of vulnerable communities are respected. In this regard, Mozambique has introduced legislation requiring investors to consult with local communities holding rights to land before undertaking major commercial enterprises such as biofuel production.

Governments also need to establish clear and fair criteria for determining "productive use" requirements and legal definitions for what constitutes "idle" land. The biofuel industry could provide support for implementing land tenure policies that safeguard the rights of local farmers by adhering to sustainable biofuel certification schemes. However, land tenure policies that secure the rights of disadvantaged communities to land can only serve their purpose if these communities understand these rights and have access to legal support services.

Although land tenure policies need to provide security to those in need, these policies also need to be flexible enough to accommodate anticipated transformations in land use and settlement patterns. It is important for planners to understand how rural communities have already begun to adapt to climate change and how this is affecting existing land tenure systems. Governments should work to completely integrate land policy considerations into their climate change adaptation strategies.

Land requirements for biofuels production

	2004[1]		2030 Reference scenario[2]		2030 Alternative policy scenario[3]		2030 Second-generation biofuels case[4]	
	million ha	% arable	million ha	% arable	million ha	% arable	million ha	% arable
United States and Canada	8.4	1.9	12.0	5.4	20.4	9.2	22.6	10.2
European Union	2.6	1.2	12.6	11.6	15.7	14.5	17.1	15.7
OECD Pacific	neg.	neg.	0.3	0.7	1.0	2.1	1.0	2.0
Transition economies	neg.	neg.	0.1	0.1	0.2	0.1	0.2	0.1
Developing Asia	neg.	neg.	5.0	1.2	10.2	2.5	11.5	2.8
Latin America	2.7	0.9	3.5	2.4	4.3	2.9	5.0	3.4
Africa and Middle East	neg.	neg.	0.8	0.3	0.9	0.3	1.1	0.4
World	**13.8**	**1.0**	**34.5**	**2.5**	**52.8**	**3.8**	**58.5**	**4.2**

Sources: farm land — FAO; land requirements — International Energy Agency analysis

1 land used for biofuel production in 2004 and as a percentage of total arable land;
2 situation in 2030 if current trends remain unchanged;
3 situation if countries adopt all of the policies they are currently considering related to energy security and CO_2 emissions;
4 situation in which some biomass for biofuels production comes from non-arable land and residues, reducing arable land requirements. neg = negligible; ha = hectares.

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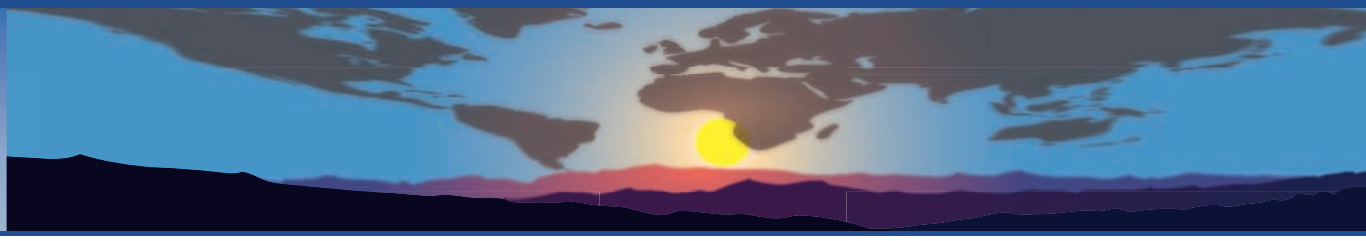

Climate change and transboundary pests and diseases

Countries spend large sums of money to eradicate and control animal and plant diseases and pests. Climate change is now creating favourable conditions for animal and plant pests and diseases in new areas as well as changing the way they are transmitted.

Charting the change

While there is clear evidence that climate change is altering the distribution of animal and plant pests and diseases, the full effects are difficult to predict. Changes in temperature, moisture and atmospheric gases can fuel growth and generation rates of plants, fungi and insects, altering the interactions between pests, their natural enemies and their hosts. Changes in land cover, such as deforestation or desertification, can make remaining plants and animals increasingly vulnerable to pests and diseases. While new pests and diseases have regularly emerged throughout history, climate change is now throwing any number of unknowns into the equation.

Some of the most dramatic effects of climate change on animal pests and diseases are likely to be seen among arthropod insects, like mosquitoes, midges, ticks, fleas and sandflies, and the viruses they carry. With changes in temperatures and humidity levels, the populations of these insects may expand their geographic range, and expose animals and humans to diseases to which they have no natural immunity.

Other climate changes can create more opportunities for vector-borne diseases. In pastoral areas, for instance, drier conditions may mean fewer watering holes, which will increase the interaction between domesticated livestock and wildlife. Increased interaction between cattle and wildebeest in East Africa could lead to a serious outbreak of malignant catarrhal fever, a highly fatal disease for cattle, since all wildebeest carry the fever virus.

Aquatic animals are also vulnerable to emerging climate-related diseases, particularly since their ecosystems are so fragile and water is such an effective disease carrier. A fungal disease called the epizootic ulcerative syndrome recently expanded to infect fish in southern Africa due in large part to increases in temperature and rainfall levels.

Protecting food and farmers

Pests and diseases have historically affected food production either directly through losses in food crops and animal production, or indirectly through lost profits from insufficient cash crop yields. Today, these losses are being exacerbated by the changing climate and its increasing volatility, threatening food security and rural livelihoods across the globe.

Developing countries with a high reliance on agriculture are the most vulnerable to today's changing patterns of pests and disease. Hundreds of millions of smallholder farmers depend solely on agriculture and aquaculture for their survival. As rural farmers struggle to produce food, poor people in nearby urban areas are left to contend with less availability in addition to higher food prices. National economies will also suffer as new pests and diseases either reduce agricultural products' access to international markets or incur higher costs associated with inspection, treatment and compliance.

Plant pests, which include insects, pathogens and weeds, continue to be one of the biggest constraints to food and agricultural production. Fruit flies, for instance, cause extensive damage to fruit and vegetable production and, as the globe's temperatures continue to increase, are finding more areas to call home. Controlling such pests often requires the use of pesticides, which can have serious side effects on

Key facts

- Pests, pathogens and weeds cause the loss of more than 40 percent of the world's food supply.
- Transboundary animal diseases such as foot-and-mouth disease, bovine spongiform encephalopathy, classical swine fever and, most recently, bird flu, are estimated to have caused economic losses in the tens of billions of US dollars.
- The 2003-2004 outbreak of desert locust in Africa affected more than 12 million hectares across 20 countries and cost more than US$400 million to combat.
- The world's oceans currently absorb a million tonnes of carbon dioxide each hour, creating an increasingly acidic environment unsuitable for sea life.

human health and the environment. This is particularly true for poor rural people, who cannot afford to use the less toxic compounds or to own proper application or safety equipment.

Climate change may also play a role in food safety. A growing number of pests and diseases could lead to higher and even unsafe levels of pesticide residue and veterinary drugs in local food supplies. And changes in rainfall, temperature and relative humidity can readily contaminate foods like groundnuts, wheat, maize, rice and coffee with fungi that produce potentially fatal mycotoxins.

Strengthening cooperation and early detection

Climate change is a global problem that is affecting every single country. Global cooperation therefore is required to respond to it.

However, given the nature of plant pests and animal diseases, more localized or regionalized strategies will be needed to be effective. Investments in early control and detection systems, including border inspections, will be key to avoid the higher costs of eradication and management. Coordinated research, including programmes related to climate change and food security from the Consultative Group on International Agricultural Research, will be needed to improve the range of options available to countries.

International trade and traffic spread transboundary animal and plant pests and diseases and alien invasive aquatic species. Countries take measures to keep new diseases and pests out. Such measures may hinder the free flow of goods and should therefore be scientifically justified and be as limited as possible in their effects on trade. New uncertainties and possibilities of introduction caused by climate change have the potential to increase these regulations and their effect on trade.

The containment of some pests and diseases may not be feasible because, for example, they are spreading too fast. New farming practices, different crops and animal breeds, and integrated pest management principles must be developed to help stem their spread. Governments may need to consider the introduction of biological control agents or new pest- or disease-resistant crops and breeds.

Governments need to strengthen national animal and plant health services as a top priority. They need to focus on basic sciences, such as taxonomy, modeling, population ecology and epidemiology. Governments should also consider how to better consolidate and organize their national animal and plant health services since they are often fragmented across different ministries and agencies.

Disease-causing insect moves north

Bluetongue disease is a devastating infection of ruminants that has historically been confined to southern Europe along the Mediterranean. However, since 1998, northern Europe has had increasingly warm weather and some midges that carry the virus that causes bluetongue have moved north. Changing temperatures have also allowed new, more populous insect species to transmit the disease, which has enhanced its spread. Bluetongue's biggest impact may be felt among cattle farmers; many countries will not accept meat exports from countries where bluetongue occurs.

Changing world of pest and disease

Climate change is only one of several "global change" factors driving the emergence and spread of plant pests and animal diseases. Additional factors include:

- globalization;
- human population growth;
- ecosystem diversity, function and resilience;
- industrial and agricultural chemical pollution;
- land use, water storage and irrigation;
- atmospheric composition;
- species interactions with hosts, predators and competitors;
- trade and human movements.

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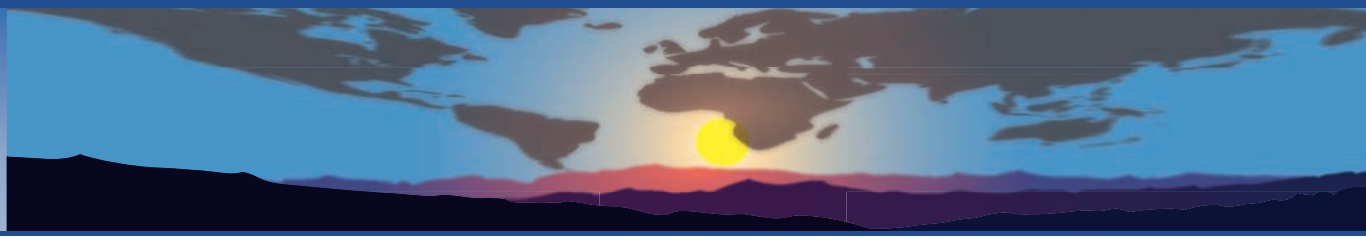

Climate change, water and food security

As a consequence of climate change, farmers will face growing unpredictability and variability in water supplies and increasing frequency of droughts and floods. However, these impacts will vary tremendously from place to place. Scientists expect that elevated temperatures will benefit agriculture in the northern latitudes, while large parts of the arid and semi-arid tropics will face declining rainfall and runoff – an ominous trend for the mostly food-insecure countries located there.

The current situation

Many intensively exploited river basins in key food producing regions are already operating at the limit of their resource base. These are worrying indicators of what is yet to come, given the dependency of urban dwellers on agricultural production and the proportion of people whose livelihoods depend on agriculture and related activities – more than two thirds in sub-Saharan Africa.

Worldwide, agriculture represents about 70 percent of water withdrawal; in sub-Saharan Africa 87 percent. But the demands of rapidly growing urban areas increase the pressure on the quality and quantity of local water resources. In addition, water is increasingly needed for environmental purposes like the replenishment of wetlands.

How food security will be affected

Water management is fundamental to maintain the stability of global food production. Reliable access to water increases agricultural yields, provides a stable supply for many key agricultural products and higher incomes in the rural areas that are home to three-quarters of the world's hungry people. Without sustainable water management across river basins, lakes and associated groundwater aquifers, local, regional and global food security is at risk. Drought is the single most common natural cause of severe food shortages in developing countries. Floods are another major cause of food emergencies. To the extent that climate change increases the variability of rainfall and increases the frequency of extreme weather events, it will hinder food security.

Changes in precipitation, evaporation of water from the soil and transpiration (water vapour given off by plants) are expected to reduce runoff by 2060 in some parts of the world, such as the Near East, Central America, northern Brazil, the western margin of the Sahara and southern Africa. In contrast, runoff will increase, for example, in northern Europe, northern China, East Africa and India. Runoff is important to replenish the water of rivers and lakes and therefore also for irrigation and maintaining ecosystem services.

Hardest hit will be rainfed agriculture – which covers 96 percent of all cultivated land in sub-Saharan Africa, 87 percent in South America and 61 percent in Asia. In marginal semi-arid zones with prolonged dry seasons, the risk of crop failures will increase. Where stability of production cannot be assured, people will be forced to migrate. By the 2080s, land unsuitable for rainfed agriculture in sub-Saharan Africa due to severe climate, soil or terrain constraints may increase by 30 to 60 million hectares.

But irrigation in large river basins and deltas are also at risk from a combination of reduced runoff, salinity (Indus), increased flooding and sea level rise (Nile, Ganges-Brahmaputra, Mekong, Yangtse), and urban and industrial pollution. These stresses on some of the prime productive land will reduce the agricultural output, biodiversity and the natural ability of ecosystems to recover – with possible negative impacts on millions of farmers and consumers across the world as food supply becomes progressively constrained.

The impacts of climate change will be uneven between countries and regions. China, with 140 million undernourished people, should gain 100 million tonnes in cereal production, while India, with 200 million

Key facts

- ↗ By 2025, 1.8 billion people will live in countries or regions with absolute water scarcity.
- ↗ Himalayan snow and ice, which provide vast amounts of water for agriculture in Asia, are expected to decline by 20 percent by 2030.
- ↗ By 2080 climate change is likely to have these impacts:
  - Seventy five percent of Africa's population could be at risk of hunger.
  - Seventy five million hectares of land currently suitable for rainfed agriculture being lost in sub-Saharan Africa.
  - Agricultural Gross Domestic Product will fall by up to 8 percent in sub-Saharan Africa and by 4 percent in Asia.
  - Demand for irrigation will grow by 5 percent to 20 percent worldwide.

undernourished, is expected to lose 30 million tonnes. Mozambique is projected to lose more than 25 percent of its agricultural productive capacity, while all scenarios show North America gaining 3 percent to 13 percent in agriculture value due to climate change.

What can be done?

Areas projected to experience lower precipitation will need to improve water storage, management and productivity. Large irrigation schemes will need to adapt to changes in water supply regimes and support will be needed for small-scale, field-based water control measures.

Five policy responses are key:

1. Include adaptation and mitigation measures for agricultural water management in national development plans.
2. Promote technical and management measures to improve the flexibility of rainfed and irrigated agriculture and reduce water losses in irrigated production systems.
3. Improve knowledge on climate change and water, and share good practice among countries and regions.
4. Promote risk management in national policies through better monitoring networks and innovative insurance products.
5. Mobilize adaptation funds to meet the challenges of water and food security under climate change.

Nile basin countries plan for climate change

A rise in temperature of three degrees Celsius could strain water supplies for an additional 155 to 600 million people in the Near East, already one of the most water-stressed regions in the world. The impacts in the Nile River basin will include increased flooding from rising sea levels in the delta along with increased exposure to water shortages. Irrigation systems are already under environmental strain from salinity, water logging and overexploitation of groundwater.

In response, an FAO project is promoting equitable use of water resources among the 10 Nile basin countries. Countries cross-reference water data with socioeconomic and environmental information to assess how projected water use patterns will affect water resources. The hope is that a strengthened common knowledge base will enhance the ability to allocate water in a way that is seen as effective and fair and that fosters rural development, poverty alleviation and regional cooperation.

Projected climate change impact on agricultural Gross Domestic Product (GDP) and cereal production in 2080

Region	Percent change in agricultural GDP	Percent change in cereal production
World	-1.5	-1.4
Developed	-0.5	+2.8
North America	+7.5	+1.3
Europe	-14.7	-3.4
Developing	-1.9	-3.9
Sub-Saharan Africa	-4.9	-0.6
Asia	-4.3	-8.6
Latin America	+3.7	+15.9
Change in world market prices	All crops: +10.5	Cereals: +19.5

Source: International Institute for Applied Systems Analysis

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